LUNAR SURFACE POTENTIAL CHANGES POSSIBLY ASSOCIATED WITH TRAVERSALS OF THE BOW SHOCK. M. R.. Collier[1], H. K. Hills[2], and T. J. Stubbs[1,3], [1]NASA's Goddard Space Flight Center, Code 673, Greenbelt, Maryland 20771 (Michael.R.Collier@nasa.gov), [2]Perot Systems Government Services, 8270 Willow Oaks Corporate Drive, Fairfax, Virginia 22031, [3]Goddard Earth Science and Technology Center, University of Maryland, Baltimore County, Maryland 21228.

Introduction: We report an analysis of seven Apollo 14 Apollo Lunar Surface Experiments Package (ALSEP) Suprathermal Ion Detector Experiment (SIDE) "resonance" events from January 1972 through January 1973. The events appear to be associated with traversals of the Moon through the terrestrial bow shock.

ALSEP/SIDE Resonance Events: The Apollo ALSEP/SIDE instrument made the first measurements of the potential of the lunar surface [1]. The SIDE instrument contains a Total Ion Detector (TID) curved plate analyzer. To determine lunar surface potentials [2], the instrument is equipped with a ground plane grid which makes contact with the lunar surface and whose potential with respect to a wire grid at the ion entrance aperture is stepped through a series of voltages ranging from zero to ±27.6 V.

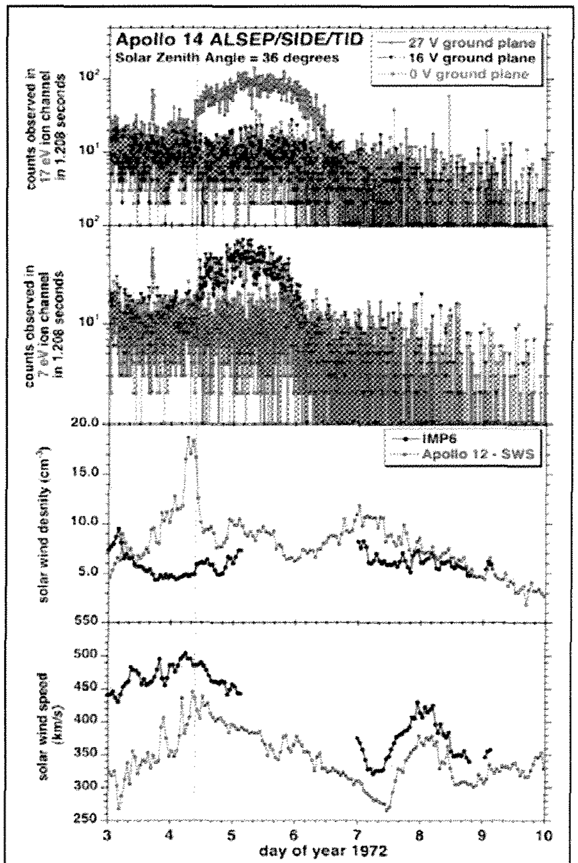

Fig. 1 – An example of an Apollo 14 ALSEP/ SIDE/TIM resonance event.

Frequently, the SIDE/TID data reveal narrow low-energy ion flux spectra that show a correlation with the ground plane stepper voltage. These events were named "resonance" events and allow a determination of the lunar surface potential. Fig. 1 shows an example of an Apollo 14 resonance event. At about 1000 UT on day 004 of year 1972, the 17 eV TID ion channel showed a dramatic count rate increase when the ground plane was at 27 V while there was no count rate enhancement in the 17 eV channel for the 16 V and 0 V ground plane settings (first panel). This indicates a lunar surface potential of about 10 V because the ground plane accelerates positive thermal ions by minus 27 V while a lunar surface potential of 10 V decelerates them so that they are observed only in the 17 eV energy channel (27 V - 10 V). The second panel which shows a 7 eV energy channel resonance indicates a surface potential of 9 V (16 V – 7 V) similar to the surface potential inferred from the 17 eV channel.

The third and fourth panels show both the IMP6 and Apollo 12 Solar Wind Spectrometer (SWS) measurements [3] of the solar wind density and speed, respectively. Prior to the time of the event, the solar wind density and speed on the lunar surface do not correlate very well with the undisturbed solar wind observed by IMP6. After event commencement, although the solar wind density observed on the lunar surface is a bit higher and the velocity a bit lower than in the undisturbed solar wind, the IMP6 and Apollo 12 SWS measurements track each other much better. This suggests that the Moon transitioned through the bow shock from the magnetosheath into the solar wind at the beginning of the resonance event.

Table 1 summarizes the seven Apollo 14 SIDE/TID resonance events analyzed in this study along with the geocentric solar ecliptic (GSE) coordinates of the Moon at the start of the event and the solar wind density, velocity, and ram pressure.

Comparison with Bow Shock Position: Fig. 2 shows the location of the Moon during the Apollo 14 SIDE events plotted with typical magnetopause and bowshock predicted locations. The solar wind conditions used in the models were solar wind pressure of 3.0 nPa, a solar wind speed of 400 km/s, a GSE-z

event	year	day	start time	Moon GSEx (R_E)	Moon GSEy (R_E)	Moon GSEz (R_E)	sw density (cm^{-3})	sw speed (km/s)	ram press (nPa)
1	1972	004	10-11	-44.0	-42.7	-2.2	5.9	486	2.3
2	1972	034	17-18	-41.0	-47.5	-5.0	6.0	401	1.6
3	1972	064	04-05	-44.8	-44.7	-5.7	6.8	388	1.7
4	1972	094	03-04	-43.2	-46.2	-4.9	6.4	382	1.6
5	1972	123	12-13	-45.4	-43.4	-3.0	5.1	522	2.3
6	1972	358	14-15	-42.3	-40.0	-2.5	11.1	486	4.4
7	1973	022	13-14	-40.6	-44.2	-4.9	5.5	374	1.3

Table 1 – Summary of the seven ALSEP/SIDE/TID resonance events analyzed in this study.

component of the solar wind magnetic field of 0.0 nT and a density of 11.2 cm^{-3}. The magnetopause model used here is from Shue et al. [4] and the bow shock model is from Howe and Binsack [5] modified by Stubbs et al. [6]. As can be seen, the events correlate very well with the bow shock, with a spread that is easily explained by variations in the solar wind ram pressure and the other parameters. This behavior was noted by Freeman and Ibrahim [7 – see their Fig. 5 which also shows that the lunar surface potential tends to be positive on the dayside and negative on the nightside].

Fig. 3 shows that the GSE-y position of the Moon at the beginning of the resonance events appears correlated with the solar wind ram pressure. This is consistent with an association between these events and traversals of the bow shock as higher ram pressure will compress the bow shock leading to encounters at GSE-y values closer to zero.

Possible Explanations: It has been known for quite some time that the terrestrial bow shock accelerates energetic particles [e.g. 8], so it is tempting to try to explain the positive drift of the lunar surface potential as due to the increased flux of suprathermal positive ions resulting from shock acceleration. However, the suprathermal ions, although extremely energetic, have a very small density relative to the solar wind electrons and, as such, contribute very little to the current balance. It may very well be the case that secondary emission is the source of the increased potentials.

References: [1] Freeman, J.W., Jr., Fenner, M. A., and Hills, H.K. (1973) *JGR, 78*, 4560-4567. [2] Manka, R.H. (1973) in Photon and Particle Interactions with Surfaces in Space, R.J.L. Grard (ed.), 347-361. [3] Neugebauer, M. et al. (1972) *PSS, 20,* 1577-1591. [4] Shue, J.H. et al. (1998) *JGR, 103*, 17691-17700. [5] Howe, H.C. and Binsack, J.H. (1972) *JGR, 77,* 3334. [6] Stubbs, T.J. et al. (2004) *JGR, 109*, A09210. [7] Freeman, J. W. and Ibrahim, M. (1975) *The Moon, 14,* 103-114. [8] Ipavich, F. M. et al. (1981) *JGR, 86,* 4337-4342.

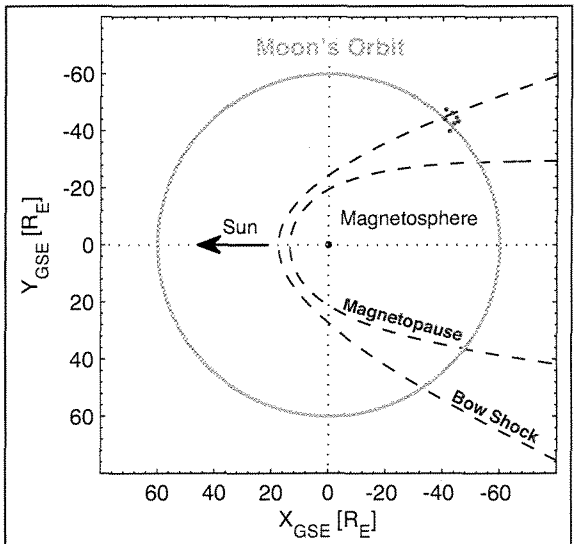

Fig. 2 – The distribution of the ALSEP/SIDE events analyzed here and a comparison with a model bow shock.

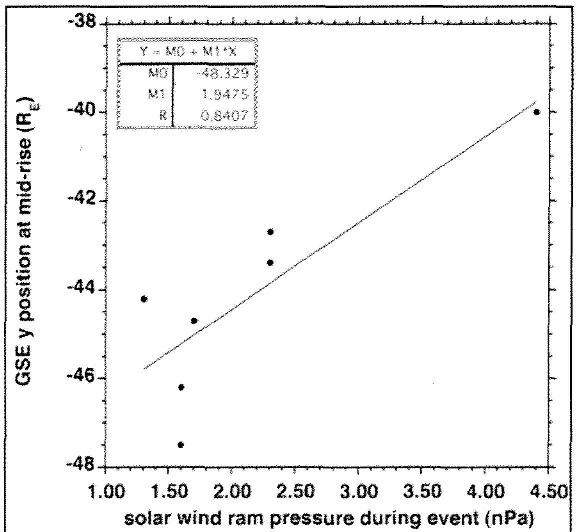

Fig. 3 – The solar wind ram pressure versus the GSE-y position of the Moon at the start of the resonance events.